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Moulded Article

The present invention concerns fibre-reinforced moulded articles made of a textile planar formation as a woven fabric of at least two fibre materials, means and a process for their production and use.

It is known to produce preforms e.g. from glass-fibre-reinforced thermoplasts. For this a thermoplastic moulding compound and glass fibre matting are processed in a pressing process into a fibre laminate material. This process is suitable mainly for the production of plate-like semi-finished products. The disadvantage is that substantially only smooth planar or plate-like structures can be produced. Structured moulded articles or components cannot be produced or only indirectly produced by way of the smooth planar plate-like structures in an additional moulding step.

EP 630 735 discloses hybrid yarn which can be processed into textile planar formations of two thermoplastic fibre materials. In one pressing process the textile planar formation is transferred to a fibre-reinforced plastic part, where a first fibre material preferably present as staple fibres is melted under the effect of pressure and heat and transforms into a matrix-forming material, while a second stretchable fibre material preferably present as endless fibres remains in the plastic part as a reinforcement material.

EP 835 741 describes the production of a premould which contains a reinforcement material in the form of rovings of staple fibres, where the fibres of the rovings have at most a slight twist in relation to each other. The preform of aligned or unaligned rovings is impregnated with a matrix material and processed into fibre-reinforced plastic parts.

EP 302 989 describes a woven fabric made from yarn for

production of fibre-reinforced plastic parts. The woven fabric contains different yarns of a first and second material. The yarns of a first material consist of a matrix-forming material and, under the effect of pressure and heat in production of the plastic part, transform into a matrix structure. The yarns of the second material constitute the fibre reinforcement in the plastic part.

The task of the present invention is to avoid these disadvantages and in particular create moulded articles and a process for their production which, starting from a fibre material, leads to moulded articles or components in one working process and in short processing times.

According to the invention this is achieved in that the woven fabric is made of a hybrid yarn of staple fibres and the staple fibres of the hybrid yarn are made of a first material or materials and a second material or materials, and the moulded article contains a matrix which is the re-set product of staple fibres brought to a plastic state of at least one thermoplastic first material and contains, embedded in the matrix, aligned fibres in the form of staple fibres of at least one second material, and the staple fibres of the second material are inorganic fibres, where a softening, melt or decomposition point of the staple fibres of the second material lies above the softening or melt point of the first material, and where the fibre orientation of the second material in the matrix corresponds to the fibre orientation of the textile planar formation.

The textile planar formations can be aligned fibres in uni-directional layers, bi-directional layers, as cut rovings, woven, knitted or laid fabrics.

Suitably, the staple fabrics of the first material have a mean length of 10 to 150 mm, suitably 30 to 120 mm, preferably 60 to 100 mm and in particular 75 to 85 mm.

Suitably, the staple fibres of the second material have a mean length of 10 to 150 mm, suitably 30 to 120 mm, preferably 60 to 100 mm and in particular 75 to 85 mm.

In particular, the textile planar formations contain staple fibres of the first and second material each with a mean length of 75 to 85 mm.

The staple fibres of the first thermoplastic material can for example contain or consist of polyamide, polyester, polycarbonate, polyurethane, polyurea, polyolefins, polystyrenes, polyacrylnitrile, polyvinyl chloride, polyvinylidene chloride, polyvinyl alcohol or polytetrafluoroethylene. Staple fibres of polyamide are preferred, such as polyamide 6, polyamide 6.6, polyamide 11 or in particular polyamide 12.

The staple fibres of the second material are for example high-temperature-resistant inorganic or organic fibres. For example, organic staple fibres can contain or consist of fully aromatic polyamides, aramides, heterocyclene-containing aromatic polyamides, polyimides, polyimidamides, polybenzimidazoles, polyoxdiazoles, polytriazoles, polythiadiazoles, polybenzoxazoles, polychinazolidines, poly-bis-benzimidazole-benzophenanthroline or chelated polyterephthaloyl-oxalamidrazone. Further examples are inorganic staple fibres which suitably contain or consist of glass, slag, stone, ceramic, quartz, silica glass, boron, silicon carbide, boron nitride, boron carbide, aluminium oxide, zirconium oxide, steel, aluminium, tungsten, carbon or graphite or can be a monocrystalline corundum or monocrystalline silicon carbide. Staple fibres are preferable made of glass, carbon or graphite. Other examples are staple fibres of natural substances which suitably consist of or contain cotton, wool, silk, or fibres of jute, sisal, coir, linen or hemp.

To control the properties, the staple fibres of

thermoplastic material and in particular the staple fibres of organic material of the second material can contain fire-inhibiting additives, pigments, colourings, fillers etc.

The temperature range of the softening, melt or decomposition point of the staple fibres of the second material is suitably selected such that this lies at least 5%, suitably 10% and in particular 30% above the softening or melt point of the first material.

In moulded articles according to the present invention, the staple fibres of the second material are formed as aligned fibres in uni-directional layers, bi-directional layers, as cut rovings, woven, knitted or laid fabrics embedded in the matrix which is the re-set product of staple fibres transferred to a plastic state of the thermoplastic first material. The fibre orientation of the original textile planar formation remains stretched. The textile planar formation of aligned fibres in uni-directional layers, in bi-directional layers, the cut rovings, woven, knitted or laid fabrics can be used in one or more layers, e.g. 1, 2, 3, 4, 5 layers etc. according to the required final thickness and strength of the moulded article. Stretching of for example up to 20% can advantageously be achieved in 1-layer textile planar formations whereas stretching of up to 35% and more is advantageously achieved with multi-layer, for example 4-layer, textile planar formations. The textile planar formations can for example have a density of 100 to 1000 g/m^2.

In the present moulded article the staple fibres of the second material in relation to the volume account for 40 to 70%, suitably 50 to 60% and preferably 53 to 59%, and accordingly the matrix of the thermoplastic first material in relation to volume accounts for 60 to 30%, suitably 50 to 40% and preferably 47 to 41%.

The present invention also comprises textile planar

formations of aligned fibres in uni-directional layers, bi-directional layers, as cut rovings, woven, knitted or laid fabrics of a mixture of staple fibres of at least two materials, where the staple fibres of at least one thermoplastic first material are present in proportions of 60 to 30% in relation to volume and the staple fibres of at least one second material are present in proportions of 40 to 70% in relation to volume, for production of the moulded article according to the invention. The staple fibres are in a hybrid yarn or a mixed yarn of the first material or materials and the second material or materials. The hybrid yarn of staple fibres is processed into a woven fabric. The woven fabric can have a weave of 1-1, 1-2, 1-3, 1-4, 1-5 etc. I.e. the weft threads can lie alternatively over or under 1, 2, 3, 4, 5 etc. warp threads. The fibre orientation can for example be 0°/90°. Particularly preferred is a satin 4-1 weave. The textile planar formations can be used in 1, 2, 3, 4 or 5 layers, where fabrics with 1, 2, 3, 4 or 5 layer fabrics are preferred. Depending on the final thickness of the moulded article a higher number of layers can be used or within a moulded article the number of layers can vary. For example, heavily stressed areas on the finished moulding can be made thicker by a multiplicity of layers, whereas less stressed areas can be constructed by one or more fewer layers. For two or more layers, the fibre orientation of the individual layers can be the same or twisted and/or offset in relation to each other.

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to each other.

The aligned fibres in uni-directional layers, bi-directional layers, as cut rovings, woven, knitted or laid fabrics, and in particular the staple fibres of a second material can on their surface be fitted with adhesion promotion agents such as adhesion size, plastic size e.g. PA 6.6 size etc. The aligned fibres in uni-directional layers, bi-directional layers, as cut rovings, woven, knitted or laid fabrics of a mixture of staple fibres of at least two materials can be subjected to a drying process before moulding where drying can be performed at high temperature, for example temperatures in a range of 60 to 100°C and/or in vacuum, preferably at 100 to 500 mbar.

The moulded articles according to the invention formed from textile planar formations with aligned fibres as woven fabrics from at least two fibre materials can be produced in that the woven fabric is made of a mixture of staple fibres of at least two materials, where the woven fabric is made of a hybrid yarn of staple fibres and the staple fibres of the hybrid yarn are made of a first material or materials and of a second material or materials, and the staple fibres of at least one thermoplastic first material account for 60 to 30% in relation to volume and those of at least one second material of inorganic fibres account for 40 to 70% in relation to volume, said fabric is preheated until the fist material softens or melts and is then placed in a tool and deformed into the moulded article under pressure application for shaping at constant high temperature of the tool and die which lies in a range below the softening or melt temperatures of the first material.

The pressing process takes place in a tool or female mould and under pressure application by means of a die or male mould for shaping and at temperatures of the die and tool below the

softening or melt temperatures of the first material. This process is also known as the cold stamping process.

Preheating can take place by radiation such as IR radiation, by convection etc. The preheating temperature depends on the melt temperature of the first material and is above the melt point of the first material and below a softening, melt or decomposition point of the second material. For example, for a polyamide 12 as a first material a preheating temperature of up to 250°C can be used. The textile planar formation can for example be heated by radiation when placed on or tensioned in a frame, or by contact heating when lying on a heat source. In the latter case adhesion of the first material to the heated surface must be prevented. In preheating the temperature of the textile planar formation must be raised to plastic deformation or melting of the first material. The preheated textile planar formation with the softened or melted first material is plastically deformed at least so far that its fibre structure disappears and a matrix forms, where the staple fibres of the second material retain their fibre structure and orientation embedded in the matrix. In other words consolidation takes place. The preheated textile planar formation is then passed to the next processing step.

The mould can for example be a tool, swage or female mould. The staple fibres can be laid in or on the tool, also known as the swage or female mould, as consolidated preheated textile planar formations in the form of aligned fibres in uni-directional layers, bi-directional layers, cut rovings, woven, knitted or laid fabrics of a mixture of staple fibres, and be subjected to pressure by means of a rigid or elastic die also known as a male mould. Deformation can be carried out at a substantially constant high temperature of the tool or tool and die. The temperature of the tool or tool and die preferably lies slightly below the softening or melt temperature of the first material. The residual heat from the preheated textile planar formation or matrix

containing the staple fibres of the second material should be sufficient for the deforming stage. In the deforming stage substantially the matrix and the staple fibres of the second material embedded therein are forced into the shape of the tool and die, forming a moulded article. Between the tool and die partial cooling takes place, where the matrix formed of the first material sets. Then the moulded article can be taken from the tool. Cooling to ambient temperature can take place outside the pressing mould. The retention time in the press for deformation can for example be less than 20 seconds, advantageously less than 10 seconds and in particular 3 to 6 seconds. A typical retention time is 5 seconds. These retention times allow a high cycle frequency in serial production of moulded articles.

Under the pressure the textile planar formations of aligned fibres in uni-directional layers, bi-directional layers as cut rovings, woven, knitted or laid fabrics, deform according to the negative form of the tool and die. Preferably, isostatic pressing occurs. Advantageously, the isostatic pressing takes place by means of a resilient rubber die. Thus, for example, moulded articles can be formed with a base and oblique or vertical side walls or for multi-part tools undercuttings can be produced. The deformation can take place on the principle of deep drawing i.e. deformation by drawing the material while the material thickness remains the same, stretch-forming i.e. by establishing the material along its side edges by means of a retainer and stretching the material with thickness reduction, a combination of stretch-forming and deep drawing i.e. only partial drawing of the material to be deformed, or by vacuum forming. Stretch-forming is preferred. On stretching during stretch-forming or combined stretch-forming and deep-drawing, the staple fibres of the second material - held in the matrix formed of the first material - undergoes an extension with simultaneous reduction in thickness. The individual fibres or fibrils which form the staple fibres are substantially surrounded by the plastic or

melted thermoplastic first material and, supported by a resulting fibre slip effect, in a fibre slip process the staple fibres are elongated under thickness reduction.

For deep drawing and/or stretch-forming, for example a drawing ratio Ω of 1 to 3, preferably 1.2 to 2.1 and in particular 1.8 to 2.0 can be applied. The drawing ratio Ω is the quotient of the applied length a to the stretched length b. The drawing ratio thus follows the formula $\Omega = a/b$. The applied length a corresponds to the actual wall length of the moulded article, the stretched length b corresponds to the length of projection of the moulded article.

The tool or female mould can be heated. For easy extraction from the mould, at least the deformation-active surface is made of chrome, chrome steel, nickel, teflon, nickel-teflon etc. The metal surfaces are suitably smooth and in particular polished or lapped. For easy extraction from the mould after the pressing process, release and/or anti-adhesion agents can be applied.

At least the deformation-active parts of a resilient rubber male mould or die are for example made of silicon rubber. The male mould or die can also be heatable.

The temperature for deformation of the consolidated material laid between tool and die depends on the softening or melt temperature of the first material. The temperature for deformation and consolidation preferably lies below the melt point and in particular below the crystallisation temperature of the first material. For example for polyamides, and preferably polyamide 12, temperatures of 70°C to 160°C are suitable, where temperatures of 110°C to 150°C are advantageous.

The application pressures are for example 25 to 100 bar, suitably 40 to 60 bar and in particular 50 bar. The thickness of the moulded article according to the invention

can be selected according to the thickness of the textile planar formation and the number of jointly pressed layers. Typical thicknesses of moulded articles are for example 0.5 to 5 mm. The thickness can vary within a moulded article. The moulded articles can for example be profile-like structured parts or plate-like parts (e.g. organo-panels) etc.

The moulded articles according to the present invention can be used in vehicles for water, road or rail or on stationary constructions. Examples of such parts are doors, hoods, side parts, front and rear skirts, bumpers, trims, bulkheads, reinforcements or holders on vehicle bodies; panels, walls, bulkheads, floors, ceilings or parts thereof on buses or rail vehicles; trims, bulkheads etc. in ships; trims, bulkheads, partition walls, floor or ceiling elements on outer facades or in the interior of stationary constructions such as buildings etc. Preferred applications are doors, hoods, side parts, front and rear skirts, bumpers, floor assemblies and roofs or parts thereof for cars and trucks.

Example:

1. A fibre matting with a density of 500 g/cm^2 of 4 layers of a satin 4-1 weave with a $0^\circ/90^\circ$ fibre orientation of staple fibre hybrid yarn, substantially 44 vol% polyamide staple fibre and 56 vol% carbon staple fibre with a mean length of 80 mm, is placed on a frame and heated by IR radiation within 75 seconds to approximately 220°C and held at this temperature for approximately 10 seconds for consolidation. The polyamide staple fibres here lose their structure and form a matrix surrounding the carbon fibres. This preheated intermediate product is laid on the tool heated to approximately 150°C, established at the edges with a retainer, and the die with the resilient rubber shaping surface is lowered into the tool. The closing time of the press is around 3 seconds, the pressure applied 50 bar and the retention time under pressure in the press 5 seconds. In

the pressing process the intermediate product of the fibre matting deforms plastically. The required contours of the moulded article are formed from the matrix by the negative form of the tool and by the die. The carbon fibres stretch or elongate during the pressing process due to the fibre slip effect under reduction of thickness according to the deformation depth of the tool. The negative form of the tool offers a tapered recess. The intermediate product of the fibre matting is pressed by the die into the recess where the staple fibres of the second material according to their position in the tapered recess extend by up to 35% of their original length. The original fibre orientation of the woven fabric is retained. After the pressure of the die is relieved, the finished moulded article can be taken from the tool, and where applicable treated by deburring and/or other processes such as painting, coating with foil or similar. The thickness of the moulded article is approximately 1.5 mm.